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ROCKY MOUNTAIN FOREST AND RANGE EXPERIMENT STATION

**An Acoustic Emissions Monitoring System
For Avalanche Snowpacks****Donald McNair, and Frank Wolfe, Jr.¹**

Unstable snow slabs may emit characteristic sounds prior to avalanche. To test this, a low-frequency monitoring system was developed to detect acoustic emissions, and was installed at Berthoud Pass, Colorado. Geophones are located in four known avalanche slide paths. All instrumentation is described.

Keywords: Acoustic emission, avalanche prediction.

Introduction

Slab instability of snow may be correlated with the level of acoustic emissions prior to avalanche. Such a correlation would allow more accurate prediction of avalanche danger.

It is known that snow does emit sounds at high frequencies², but due to the poor propagation of such high frequencies through snow, they do not appear to be useful. The instrumentation described here was developed to detect acoustic emissions in the frequency range of 0.5 Hz to 3 kHz. A low-frequency recording system would also give greater coverage from a single geophone.

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²St. Lawrence, W., and C. Bradley. 1973. Ultrasonic emissions in snow. p. 1-6. In *Advances in North American avalanche technology: 1972 symposium*. USDA For. Serv. Gen. Tech. Rep. RM-3, 54 p. Rocky Mt. For. and Range Exp. Stn., Fort Collins, Colo.

The system was installed at Berthoud Pass, Colorado, with geophones located in four known slide paths. Amplification, filtration, and recording instruments were located within a nearby heated instrument building. Since the distance from the slide paths to the instrument recording building was up to 400 m, a pre-amplifier was developed to transmit the signals on the long cable.

Geophones

The geophones used are Geo Space, Model Hs-1³, with a 4.5 Hz resonance frequency. Used with 330 Ω damping resistance, their frequency is flat from 5 Hz to above 100 Hz. At 215 Hz (one octave), the response is 9.5 db down. Since no calibration equipment was available, the manufacturer's calibration was used.

³Trade and company names are used for the benefit of the reader, and do not imply endorsement or preferential treatment by the U.S. Department of Agriculture.

The geophones and the pre-amplifiers were mounted on 30- by 30-cm sheets of expanded metal grills. Thirty m of shielded cable supplied the pre-amplifier with ± 15 V from a power supply located in a junction box, and the signal return to the junction box. The signal then was carried to the instrument recording building by up to 400 m of shielded cable. The junction boxes received 110-v a.c. power by separate conductors from the instrument recording building. The junction boxes were located at accessible points above the slide path (fig. 1).

Pre-Amplifiers

The pre-amplifiers were fabricated with Zeltex ZA801 M1 operational amplifiers. Component selection gave the desired $330\ \Omega$ input resistance to critically dampen the geophones and a nominal gain of 1,000 to drive the signal the length of the

cable to the instrument recording building. A $3-k\Omega$ resistor in series with the output was found to be necessary to stop oscillation. Pre-amplifiers were constructed on printed circuit cards made to fit in an aluminum minibox 6.4 cm wide and 4.1 cm high. This box was filled with potting compound to insure weather tightness. The pre-amplifiers were mounted with the sensor and placed in the avalanche area under the snow. The circuit is diagrammed in figure 2.

The trim potentiometers were first adjusted for 0-V output with the input shorted. Calibration consisted of injecting a 1-mV peak-to-peak signal supplied by a HP 3300A function generator across the input end of the 100-ft shielded cable while varying the frequency of the input signal. The calibration range was from 0 to 10 kHz. Voltage readings were made with a Teletronix 564 oscilloscope. Typical pre-amplified calibration readings with 10-mV peak-to-peak signal input was 10.0, 8.85, and 1.6 V at frequencies of 100 Hz, 1kHz, and 10 kHz respectively.

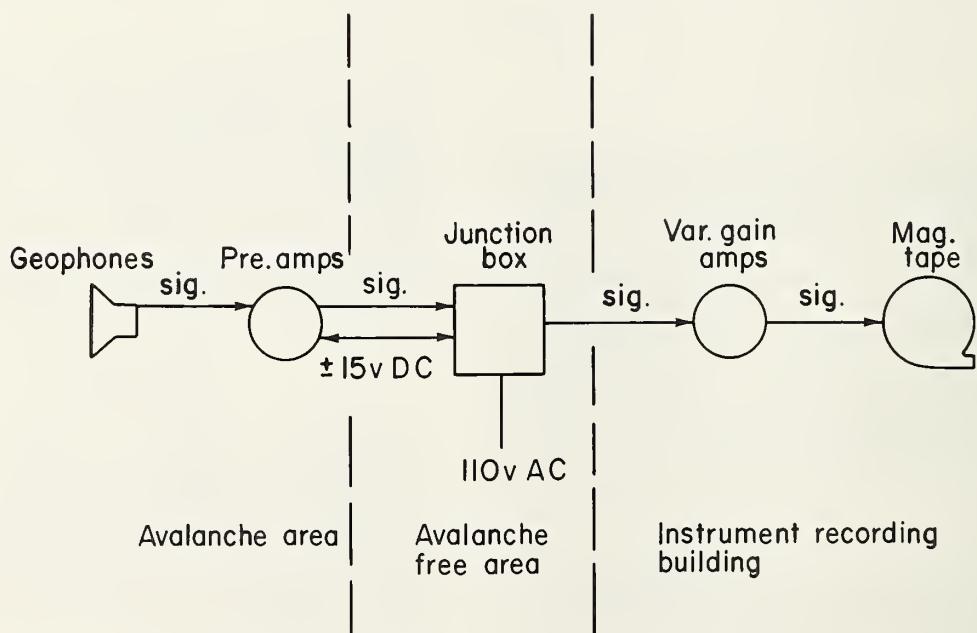


Figure 1.—Block diagram showing location of components and route of signal from geophones to recording tapes.

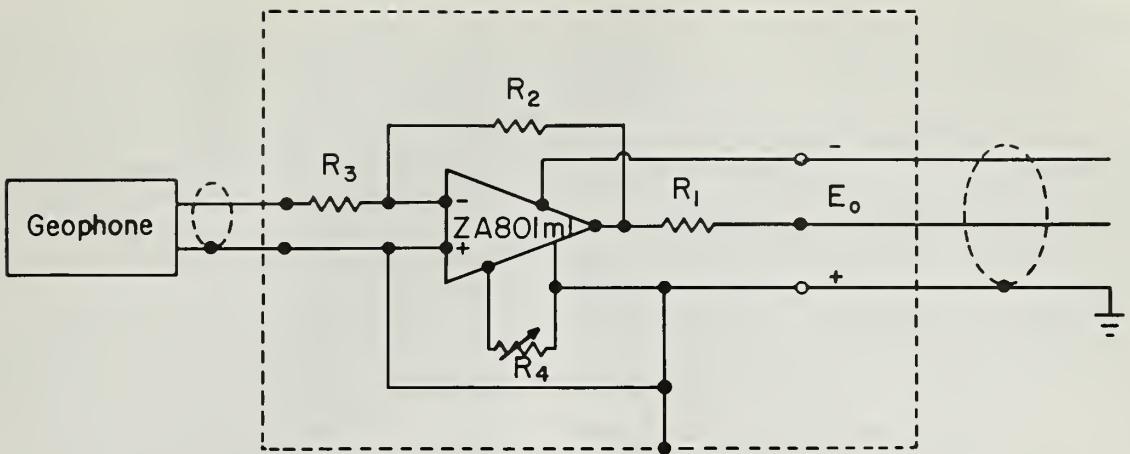


Figure 2.—Pre-amplifier components.

op — amp. — Zeltex-Za801ml
R1 — 3 k Ω , 1% tolerance

R2 — 330 k Ω , 1% tolerance
R3 — 330 Ω , 1% tolerance

R4 — 10 turns, 1 k Ω

Variable gain amplifier

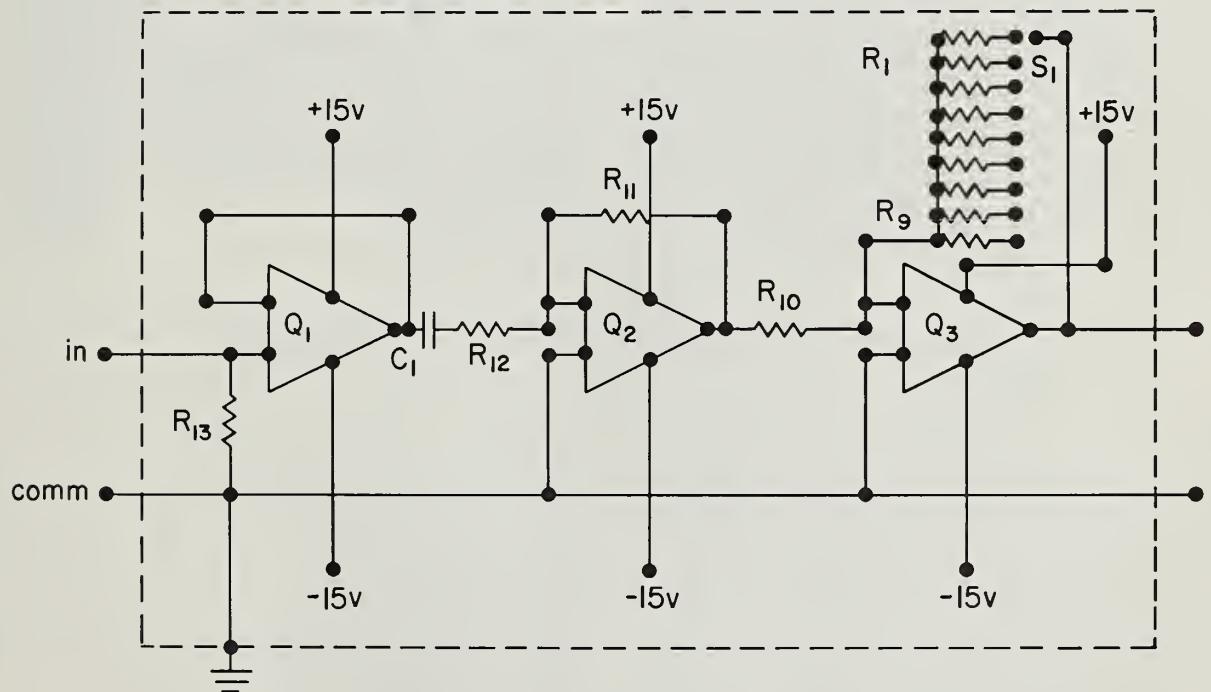


Figure 3.—Variable gain amplifier components.

R1 — 120 k Ω
R2 — 64 k Ω
R3 — 32 k Ω
R4 — 16 k Ω
Note: All resistors are 1% tolerance.

R5 — 8 k Ω
R6 — 4 k Ω
R7 — 2 k Ω
R8 — 1 k Ω

R9 — 500 k Ω
R10 — 1 k Ω
R11 — 100 k Ω
R12 — 10 k Ω

S1 — spectral rotary

C1 — 25 microfarad

Because the most sensitive scale on the Tektronix 3A7Z plug-in is only 10 mV per division, a more accurate means of measuring the input signal was needed. Using the Tektronix scope, the output signal of the HP 3300A function generator was adjusted to 1.0 V peak to peak. This voltage was then divided by a $100 \div 1$ divider. The output from the divider was adjusted to give 0.0035 rms (10 mV peak to peak) at 100 Hz, as read on a HP 3450A voltage meter. The scope was then taken off "calibration" position and the gain potentiometer of the scope adjusted to give eight divisions, which then equaled the 1.0-V peak-to-peak signal across the input to the divider. This gave an accurate 10-mV peak-to-peak signal across the output of the divider at all frequencies by adjusting the function generator for the eight division signals across the divider input.

Rms noise measured less than 1 mV at the end of the cable with the pre-amplifier input shorted.

Variable Gain Amplifiers

The main amplifiers were fabricated with three 741 Operational Amplifiers. The amplifiers were put on printed circuit cards, with card connectors to be plugged into a grounded, shielded panel rack. B.N.C. connectors were used for input to the amplifiers and as output to the magnetic tape recorder. The outside shell was grounded. By use of a selector switch, the gain could be varied in nine

steps, from X 5 to X 1200, by changing feedback to the amplifiers. These steps were made by switching through nine 1% tolerance resistors. The switch was a miniature card mount multi-position rotary. A $25\text{-}\mu\text{F}$ capacitor was placed between the first and second steps to prevent any direct current across the input from blocking the final stages (fig. 3). As seen from the calibration (table 1), this did little to upset the low-frequency response.

The calibration consisted of injecting a 10-mV peak-to-peak signal across the input, and then measuring the output with a 564 Teletronix scope. The frequencies from the HP 3300A were varied in five steps: 1, 10, and 100 Hz; and 1 and 10 kHz. The results are shown in table 1. The 10-mV peak-to-peak signal was obtained the same as the calibration of the pre-amplifiers.

The Teledyne Geo-Tech Model No. 19429 slow-speed magnetic tape recorder was run at a tape speed of .06 in per sec. Its frequency response using direct-record electronics is 0.5 to 125 Hz \pm 3 db. It records 16.5 days on a 7200-ft reel of 1 $\frac{1}{2}$ mil Ampex instrumentation tape. The recorder was capable of recording 14 channels at one time. One of these channels was used to record the binary coded time of day from a Datatron Model No. 3150 time code generator. A second channel was used to record the output from an anemometer located above one of the slide paths. The remaining 12 channels were available for recording the geophone signals. Various combinations of amplification and filtering could be used to obtain optimum signals.

Table 1.—Typical amplifier calibration (nominal gain, $\times 5$ through $\times 1200$) in output voltage (peak-to-peak) with 10 mV (peak-to-peak) input at various frequencies and gain settings.

Gain settings	Frequency				
	1 Hz	10 Hz	100 Hz	1 kHz	10 kHz
1200	10.8	12.2	12.2	12.0	8.0
640	5.8	6.6	6.6	6.6	5.6
320	3.0	3.3	3.4	3.3	3.2
160	1.52	1.6	1.62	1.6	1.6
80	.75	.81	.82	.82	.82
40	.36	.41	.41	.41	.40
20	.18	.20	.20	.20	.20
10	.09	.10	.10	.10	.10
5	.042	.051	.051	.051	.051